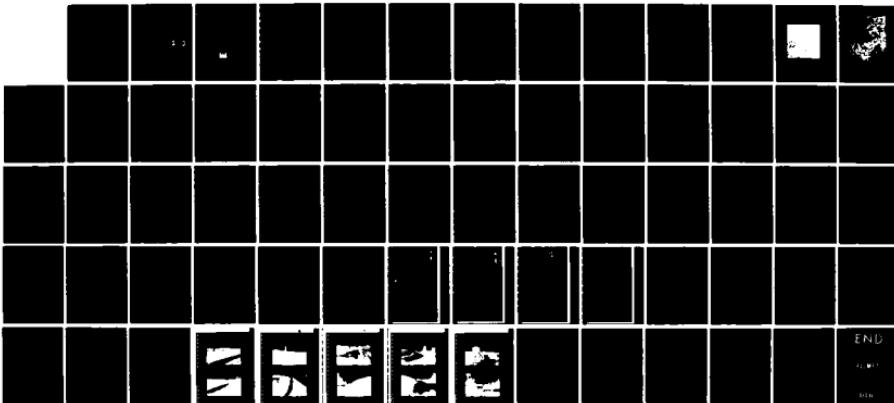


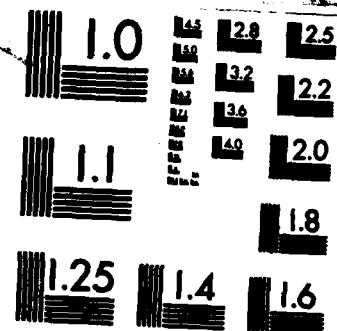
AD-A154 333 NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS 1/1  
MERRIMACK RIVER BASIN. (U) CORPS OF ENGINEERS WALTHAM  
MA NEW ENGLAND DIV SEP 79

UNCLASSIFIED

F/G 13/13

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A154 333

DTIC ACCESSION NUMBER



LEVEL

PHOTOGRAPH THIS SHEET

1

INVENTORY

MA. 00743

DOCUMENT IDENTIFICATION

Sep 1979

DISTRIBUTION STATEMENT A

Approved for public release  
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR

NTIS GRA&I

DTIC TAB

UNANNOUNCED

JUSTIFICATION



BY

DISTRIBUTION /

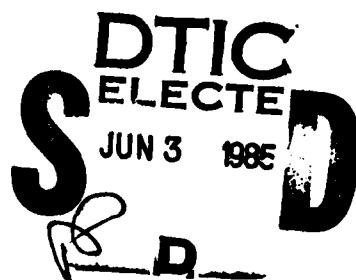
AVAILABILITY CODES

DIST

AVAIL AND/OR SPECIAL

A-1

DISTRIBUTION STAMP



DATE ACCESSIONED

DATE RETURNED

85 6 3 031

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NO.

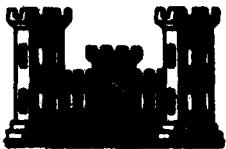
PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDAC

AD-A154 333

MERRIMACK RIVER BASIN  
LAWRENCE, MASSACHUSETTS

LAWRENCE RESERVOIR  
MA 00743

**PHASE I INSPECTION REPORT  
NATIONAL DAM INSPECTION PROGRAM**



**DEPARTMENT OF THE ARMY  
NEW ENGLAND DIVISION, CORPS OF ENGINEERS  
WALTHAM, MASS. 02154**

**SEPTEMBER 1979**

~~UNCLASSIFIED~~

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER <b>MA 00743</b>	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) <b>Lawrence Reservoir</b>		5. TYPE OF REPORT & PERIOD COVERED <b>INSPECTION REPORT</b>
6. NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		7. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) <b>U.S. ARMY CORPS OF ENGINEERS NEW ENGLAND DIVISION</b>		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS <b>DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA. 02254</b>		12. REPORT DATE <b>September 1979</b>
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES <b>. 55</b>
		15. SECURITY CLASS. (of this report) <b>UNCLASSIFIED</b>
		16a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) <b>APPROVAL FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED</b>		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) <b>DAMS, INSPECTION, DAM SAFETY, Merrimack River Basin Lawrence Massachusetts</b>		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <p>The 410 ft. by 700 ft., stone lined reservoir which is located near the top of Tower Hill is almost entirely surrounded by an earthfill embankment. The embankment is 1870 ft. long and has a maximum height of 29 ft. There are deficiencies which must be corrected to assure the continued performance of the reservoir and embankment. Generally, both are in good condition.</p>		

LAWRENCE RESERVOIR

MA 00743

MERRIMACK RIVER BASIN  
LAWRENCE, MASSACHUSETTS

PHASE I INSPECTION REPORT  
NATIONAL DAM INSPECTION  
PROGRAM

NATIONAL DAM INSPECTION  
PROGRAM

PHASE I INSPECTION REPORT

BRIEF ASSESSMENT

Identification No.: MA00743

Name of Dam: Lawrence Reservoir

Town: Lawrence

County and State: Essex County, Massachusetts

Stream: None - surface drainage to the Merrimack River  
and its tributary, Spicket River

Date of Inspection: April 12, 1979

Lawrence Reservoir provides storage and equalizing pressure for part of the water system to Lawrence and Methuen. The 410-foot by 700-foot, stone-lined reservoir which is located near the top of Tower Hill is almost entirely surrounded by an earthfill embankment. The embankment is 1,870 feet long and has a maximum height of 29 feet. The crest of the embankment varies from El (elevation) 210.2 to 210.6. An earthfill dike at the center of the reservoir separates the reservoir into a north and a south basin. The maximum operating pool is at El 208.4 (top of stone lining). Water is discharged from the reservoir through two 30-inch conduits leading out of a gate house. The invert of the conduits is at about El 183. The conduits merge to form a 30-inch water supply line for Lawrence. An open 30-inch bypass line from the water supply line directs water to Methuen.

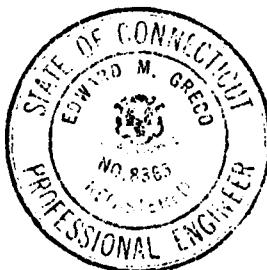
There are deficiencies which must be corrected to assure the continued performance of the reservoir and embankment. This conclusion is based on the visual inspection of the site, a review of available data, and a review of operating procedures. Generally, the reservoir and embankment are in good condition.

LAWRENCE RESERVOIR

The following deficiencies were observed at the site: seepage and efflorescence in the gate chamber of the gate house, cracking and efflorescence in the access tunnel to the gate chamber, corrosion of the gate valves and outlet conduits, difficulty operating the sluice gates, localized erosion of the outside slopes of the embankments, and trees growing on the slopes of the embankment.

Based on the Corps of Engineers' guidelines, the reservoir has been placed in the "small" size and "high" hazard category. The drainage area is 6.43 acres (0.01 square mile) and consists of the surface area of the reservoir. A test flood inflow (full probable maximum flood (PMF)) of 18.16 inches of rainfall during a 6-hour period results in the reservoir pool at El 209.9, which is 0.3 foot below the lowest elevation on the crest of the embankment. Therefore, the reservoir can contain 100 percent of the test flood without overtopping the embankment.

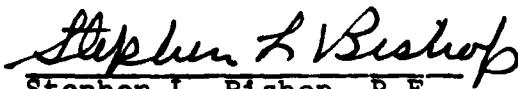
It is recommended that the Owner employ the services of a qualified engineering consultant to conduct a static and seismic stability analysis of the embankment. In addition, the Owner should repair the deficiencies listed above, as described in Section 7.3. The Owner should also implement a program of biennial technical inspections, a plan for surveillance of the embankment during and after periods of unusually heavy rainfall, and a system for notifying nearby residents in case of an emergency at the project. The measures outlined above and in Section 7 should be implemented by the Owner within a period of 2 years after receipt of this Phase I Inspection Report.



  
Edward M. Greco, P.E.  
Project Manager  
Metcalf & Eddy, Inc.

Connecticut Registration  
No. 08365

Approved by:

  
Stephen L. Bishop, P.E.  
Vice President  
Metcalf & Eddy, Inc.

Massachusetts Registration  
No. 19703



LAWRENCE RESERVOIR

This Phase I Inspection Report on Lawrence Reservoir has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

CHARLES G. TIERSCH, Chairman  
Chief, Foundation and Materials  
Branch  
Engineering Division

FRED J. RAVENS, JR., Member  
Chief, Design Branch  
Engineering Division

SAUL C. COOPER,  
Member Chief, Water Control Branch  
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR  
Chief, Engineering Division

LAWRENCE RESERVOIR

## PREFACE

This report is prepared under guidance contained in Recommended Guidelines for Safety Inspection of Dams, for a Phase I Investigation. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigations, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general conditions and the downstream damage potential.

LAWRENCE RESERVOIR

## TABLE OF CONTENTS

	<u>Page</u>
BRIEF ASSESSMENT	
PREFACE	
OVERVIEW PHOTO	iii
LOCATION MAP	iv
REPORT	
SECTION 1 - PROJECT INFORMATION	1
1.1 General	1
1.2 Description of Project	1
1.3 Pertinent Data	6
SECTION 2 - ENGINEERING DATA	10
2.1 General	10
2.2 Construction Records	10
2.3 Operating Records	10
2.4 Evaluation	11
SECTION 3 - VISUAL INSPECTION	12
3.1 Findings	12
3.2 Evaluation	14
SECTION 4 - OPERATING PROCEDURES	15
4.1 Procedures	15
4.2 Maintenance of Dam	15
4.3 Maintenance of Operating Facilities	15
4.4 Description of Any Warning System in Effect	16
4.5 Evaluation	16
SECTION 5 - HYDRAULIC/HYDROLOGIC	17
5.1 Evaluation of Features	17

LAWRENCE RESERVOIR

## TABLE OF CONTENTS (Continued)

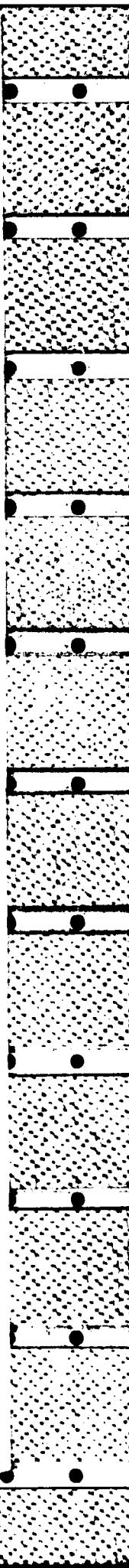
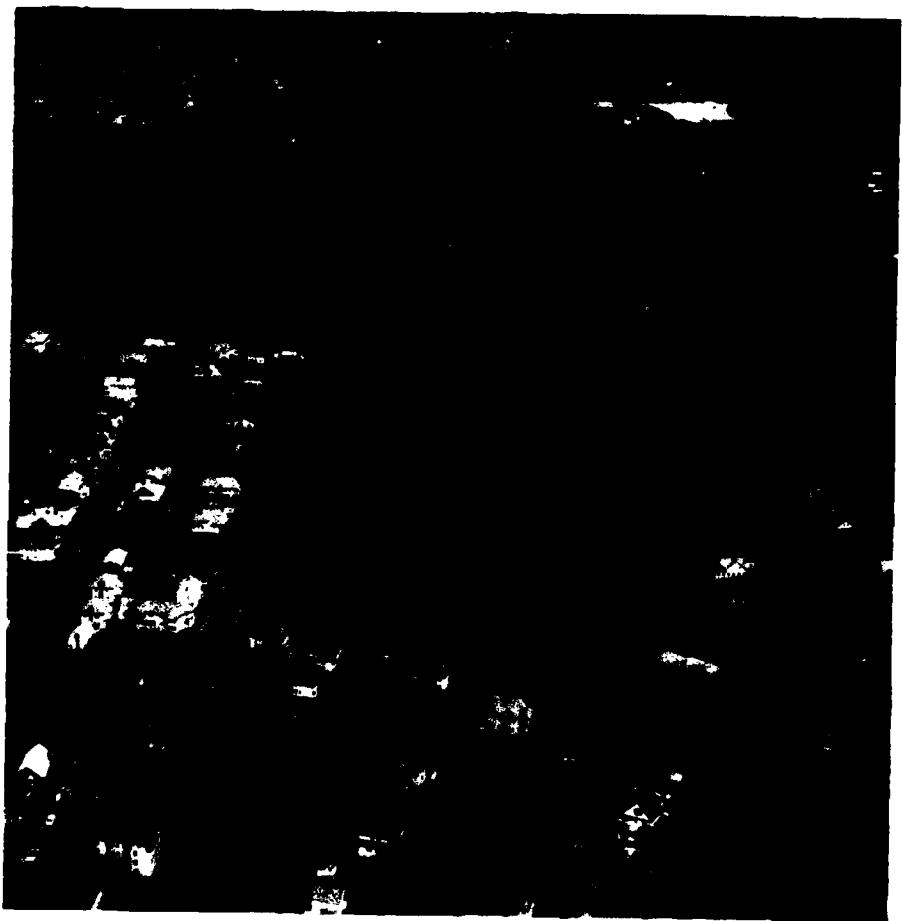
	<u>Page</u>
SECTION 6 - STRUCTURAL STABILITY	21
6.1 Evaluation of Structural Stability	21
SECTION 7 - ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES	23
7.1 Dam Assessment	23
7.2 Recommendations	24
7.3 Remedial Measures	24
7.4 Alternatives	25

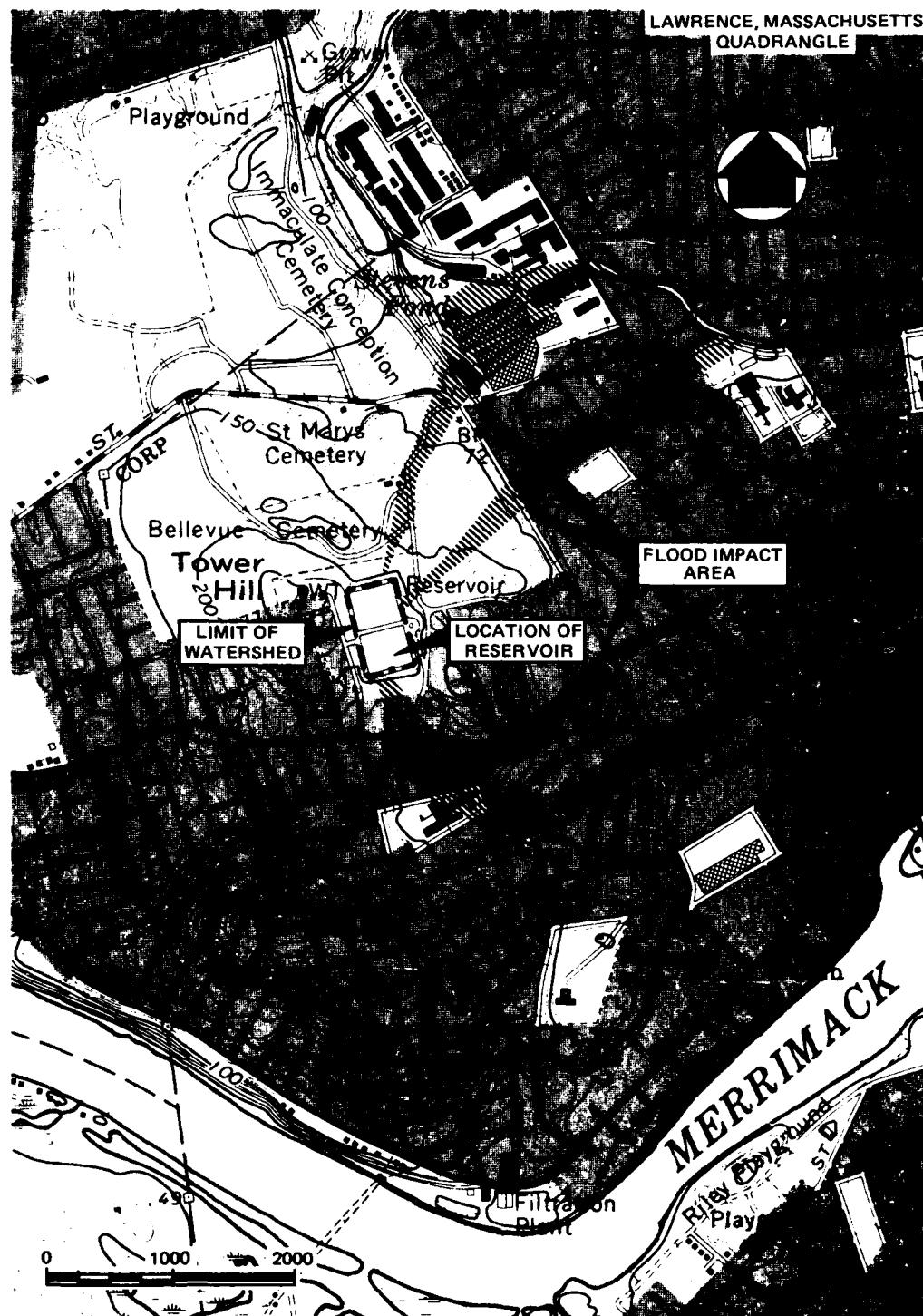
## APPENDIXES

- APPENDIX A - PERIODIC INSPECTION CHECKLIST
- APPENDIX B - PLANS OF RESERVOIR AND PREVIOUS  
INSPECTION REPORTS
- APPENDIX C - PHOTOGRAPHS
- APPENDIX D - HYDROLOGIC AND HYDRAULIC  
COMPUTATIONS
- APPENDIX E - INFORMATION AS CONTAINED IN THE  
NATIONAL INVENTORY OF DAMS

LAWRENCE RESERVOIR

**OVERVIEW  
LAWRENCE RESERVOIR**





LOCATION MAP – LAWRENCE RESERVOIR

NATIONAL DAM INSPECTION  
PROGRAM

PHASE I INSPECTION REPORT

LAWRENCE RESERVOIR

SECTION 1

PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Metcalf & Eddy, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Contract No. DACW 33-79-C-0054, dated March 27, 1979, has been assigned by the Corps of Engineers for this work.

b. Purpose:

- (1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.
- (2) Encourage and assist the States to initiate quickly effective dam safety programs for non-Federal dams.
- (3) Update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. The reservoir is located on Tower Hill in the City of Lawrence, Essex County, Massachusetts (see Location Map). The coordinates of this location are latitude 42 deg. 42.4 min. north and longitude 71 deg. 11.0 min. west.

LAWRENCE RESERVOIR

b. Description of Dam and Appurtenances. Lawrence Reservoir is a 410-foot by 700-foot stone-lined reservoir almost entirely surrounded by an earthfill embankment (see Figures B-1 through B-4 and photographs in Appendix C). The embankment forms the north, east, south, and southwest sides of the reservoir. The northwest side is cut into a hill. An earthfill dike at the center of the reservoir separates the reservoir into a north and a south basin.

The embankment is 1,870 feet long and has a maximum height of 29 feet. The crest of the embankment is 24 feet wide and varies from El 210.2 to 210.6. There is an asphalt-paved walkway 15 feet wide on the crest. On the inside edge of the walkway is a curb 0.3 feet high and an iron fence surrounding the reservoir. The inside slopes of the reservoir are lined with cut stone blocks to the maximum operating pool level (El 208.4), and covered with grass from the top of the lining to the crest (see photograph No. 4, page C-2). The inside slopes are 1.5:1 (horizontal: vertical). The bottom of the reservoir is lined with cobbles and is at about El 181. The outside slopes of the embankment are covered with grass and slope at 2:1. There is a berm about halfway down the outside slope on the north, east, and south sides of the reservoir.

The dike across the middle of the reservoir has a crest at El 204.5 and is normally submerged. It is described in an early inspection report (see page B-6) as an embankment 22 feet wide at the crest with slopes at 2:1. Cut stone blocks cover the crest and slopes of the dike.

Lawrence Reservoir provides storage and equalizing pressure for a water supply system. Water is pumped from a treatment plant into the reservoir through a 30-inch, cast-iron pipeline. This conduit discharges at the center of the crest of the dike (see photograph No. 1, page C-1). The rim of the inflow conduit is at El 210.0, according to the Lawrence Water

#### LAWRENCE RESERVOIR

Department. Outflow from the reservoir is carried by two 30-inch, cast-iron pipelines which lead out of a gate house located at the crest of the embankment on the south side of the reservoir. The gate house is constructed of brick with a stone masonry foundation. A pipe from the north basin of the reservoir extends through the dike and into the east half of the gate house. Water from the south basin discharges directly into the wet well of the gate house through an arched opening. Water then flows into a screen chamber in the gate house controlled by three 3-foot by 4-foot, metal sluice gates. The two 30-inch pipelines lead from the screen chamber into an underground gate chamber located on the south side of the gate house. Available drawings indicate that the invert of the conduits is at about El 183. The main gate valves for the outflow conduits are located in the gate chamber. Access to the chamber is either through two manholes from the ground surface or through a 4.8-foot wide, 8-foot high tunnel from the toe of the embankment (see Figure B-4). The pipelines continue downstream and merge to form a single 30-inch conduit which distributes water to Lawrence. There is a 30-inch bypass off the distributing line which carries water to Methuen. There are emergency shut-off valves for these lines located in wells at the south property line of the reservoir. There is also a 20-inch conduit connecting the 30-inch distributing line to the 30-inch pipeline beneath Ames Street (southwest of reservoir). The 20-inch conduit contains a gate valve, but is normally kept closed.

There are two 16-inch, low-level drain lines used to empty the reservoir for cleaning or repairs. The drain for the south basin is at El 179 and is controlled by a gate valve located in the gate chamber. The drain line connects into a 10-inch storm sewer. The drain for the north basin is reportedly controlled by a valve located in a manhole north of the reservoir. The drain leads to a 12-inch storm sewer.

#### LAWRENCE RESERVOIR

- c. Size Classification. Lawrence Reservoir is classified in the "small" category, since the embankment has a maximum height of 29 feet, and the reservoir has a maximum storage capacity of 146 acre-feet.
- d. Hazard Classification. The reservoir is located on top of a hill and on the edge of thickly developed areas of Lawrence. The area immediately around the reservoir is used as a park, and there are tennis courts at the toe of the south embankment. Dense residential development occurs along the west, south and southeast sides of the reservoir. A cemetery is located along the north and northeast sides of the reservoir, however, residences and factory buildings are located 1200 to 2000 feet downhill and northeast of the reservoir.

Failure of the embankment when the reservoir level is at the crest would produce a flood wave 7 feet high. This is assuming that only one basin of the reservoir would be fully drained by failure. If the south basin is drained, the flood would result in the loss of more than a few lives and excessive property damage (see alternative areas of flood impact shown on Location Map). Accordingly, the dam has been placed in the "high" hazard category.

- e. Ownership. The reservoir and embankment have been owned since 1875 by the City of Lawrence Water Department, 200 Common Street, Room 304, Lawrence, Massachusetts 01841. Mr. John Greeley (telephone 617-685-5754) granted permission to enter the property and inspect the dam.
- f. Operator. Personnel from the Lawrence Water Department operate the dam. Mr. Norm Basavus is the resident caretaker.
- g. Purpose of Dam. The reservoir is part of the water supply system for the cities of Lawrence and Methuen. The reservoir provides storage and equalizing pressure prior to distribution. The capacity of the reservoir when the water is 27.5 feet deep (maximum operating pool) is about 44 million gallons. The area around the reservoir is also used as a public park.

LAWRENCE RESERVOIR

h. Design and Construction History. The reservoir and embankment were constructed between 1873 and 1875. The contractors were John B. Darcy Co. and Patrick Kevucew. The structures appear to have been built essentially as shown on the drawings dated January 1873 (see Figures B-3 and B-4). However, the field survey conducted during the Phase I inspection indicates that the elevations of the embankment and maximum operating pool are about 3 feet higher than what is shown on a later drawing dated 1935.

A review of previous inspection reports (pages B-5 through B-10) indicates that several repairs have been made in the past. In 1935 the outside slopes of the north and east embankments were stripped, reloamed, and re-seeded. In 1939, grout was placed between the stone blocks lining the inside of the reservoir. Also, a leak was repaired in the 30-inch conduit from the north basin, and a 12-inch storm sewer was connected to the 16-inch drain from the north basin. In 1976, emergency shut-off valves were installed on the two 30-inch distributing lines downstream of the reservoir.

i. Normal Operating Procedures. Under normal conditions, water is pumped from a treatment plant into the reservoir through a pipeline which discharges at the center of the reservoir. The water level is monitored at the treatment plant and also read three times a day at the reservoir. Gate valves on the outflow conduits and distributing lines are kept open, except for one on a 20-inch line connecting to the pipeline under Ames Street. The gate valves are reportedly checked periodically. Three sluice gates which control flow into the screen chamber of the gate house are also kept open. Occasionally in the past, the low-level drain lines have been opened for cleaning or repairs. This was last done in 1962.

#### LAWRENCE RESERVOIR

### 1.3 Pertinent Data

- a. Drainage Area. The reservoir is located on top of a hill. Its rim is above the surrounding ground except along the northwest side, where a small amount of surface runoff would flow down the hillside and onto the crest of the embankment. The crest slopes to the north and south and would direct runoff away from the reservoir. Also, there is a curb around the inside of the crest which would prevent any appreciable runoff from entering the reservoir. The drainage area, therefore, consists only of the surface area of the reservoir (see Location Map) which is 6.34 acres (0.01 square miles).
- b. Discharge. Normal discharge is through two 30-inch pipelines which lead from the gate house into a 30-inch water supply line. There is an open 30-inch bypass off the supply line. The rate of discharge is controlled by demand from downstream water use. The invert of the outflow conduits is at about El 183 in the gate house. Flow into the conduits can be regulated by three sluice gates located in the gate house or by two gate valves located in an underground gate chamber. There are also two emergency shut-off valves downstream on the water supply line and on the bypass line. All of these valves and the sluice gates are normally kept open. In an emergency, water can also flow out of the water supply line into a 20-inch conduit which connects to the 30-inch pipeline (inflow conduit) beneath Ames Street. The gate valve for the 20-inch conduit is located in a manhole and is normally kept closed.

A test flood inflow (full PMF) of 18.16 inches of rain during a 6-hour period will raise the reservoir to El 209.9. This is based on the assumption that the rate of inflow due to pumping equals the rate of outflow due to consumption. The test flood pool is 0.3 foot below the lowest elevation on the crest of the embankment. Therefore, the reservoir can contain 100 percent of the test flood without overtopping the embankment.

LAWRENCE RESERVOIR

The reservoir was completed in 1875 and has never reportedly been overtopped. The water level, which is controlled by pumping, is recorded at the treatment plant. The maximum reservoir level is reported to be 208.4.

- c. Elevation (feet above Mean Sea Level (MSL)). A benchmark was established at El 210.0 on the rim of the inflow conduit at the center of the reservoir. This elevation was provided by the City of Lawrence and is shown on a drawing of the reservoir dated 1935.

- (1) Top of dam: 210.2 to 210.6
- (2) Test flood pool: 209.9
- (3) Design surcharge: Unknown
- (4) Full flood control pool: Not Applicable (N/A)
- (5) Maximum operating pool: 208.4
- (6) Spillway crest: None
- (7) Upstream portal invert diversion tunnel: None
- (8) Stream bed at centerline of dam: N/A
- (9) Maximum tailwater: N/A

d. Reservoir

- (1) Length of maximum pool: 700 feet
- (2) Length of maximum operating pool: 700 feet
- (3) Length of flood control pool: N/A

e. Storage (acre-feet)

- (1) Test flood surcharge (net): 9.5 at El 209.9
- (2) Top of dam: 146 at El 210.2
- (3) Flood control pool: N/A

LAWRENCE RESERVOIR

(4) Maximum operating pool: 135

(5) Spillway crest: N/A

f. Reservoir Surface (acres)

\*(1) Top of dam: 6.3

\*(2) Test flood pool: 6.3

(3) Flood-control pool: N/A

(4) Maximum operating pool: 6.3

(5) Spillway crest: N/A

g. Dam (earth embankment around reservoir)

(1) Type: earthfill

(2) Length: 1,870 feet (perimeter embankment)

(3) Height: 29 feet (maximum)

(4) Top width: 24 feet

(5) Side slopes: inside - 1.5:1  
outside - 2:1

(6) Zoning: Unknown

(7) Impervious core: puddled clay

(8) Cutoff: clay core extending 12 feet below  
bottom of reservoir

(9) Grout curtain: None

h. Spillway. There is no spillway at this site.  
Normal discharge flows through two 30-inch  
pipelines which lead into a 30-inch water  
supply line.

\*Based on the assumption that the surface area will not  
increase significantly with changes in reservoir ele-  
vation from 208.4 to 210.2.

LAWRENCE RESERVOIR

i. Regulating Outlets. Under normal conditions, the pool level is controlled by the rate of pumping into the reservoir. In an emergency, the pumps can be shut down, and the reservoir would be lowered by outflow into the distribution system. Water is conducted out of the reservoir through two 30-inch pipelines. These join to form a 30-inch supply line which has an open 30-inch bypass line. The invert of the outflow conduits in the gate house is at about El 183. Flow through the conduits can be stopped by sluice gates in the gate house, gate valves in the gate chamber, or emergency shut-off valves on the supply lines.

There are also two 16-inch low-level drain lines used to empty the reservoir for cleaning or repairs. The drain for the south basin is at El 179 and is controlled by a gate valve in the gallery of the gate house. The drain line connects into a 10-inch storm sewer. The drain for the north basin is reportedly controlled by a valve located in a manhole north of the reservoir. The drain leads to a 12-inch storm sewer (see construction notes on page B-8). Because the storm sewers are undersized, the drain lines should be only partially opened to avoid overflowing the downstream manholes.

## SECTION 2

### ENGINEERING DATA

2.1 General. Drawings dated January 1874 showing proposed construction of the reservoir, embankment, and gate house were obtained from the City of Lawrence, Engineering Department. Two of these drawings are included in Appendix B (see Figures B-3 and B-4). A plan of the reservoir dated April 1935 showing the property boundaries was reviewed at the City of Lawrence, Engineering Department. A plan and section of the reservoir dated November 1935 showing elevations of the operating pool and inflow conduit was obtained from personnel at the treatment plant. A plan of the gate house dated December 1938 showing the locations of gate valves and sluice gates was obtained from the caretaker at the reservoir. The drawings dated 1935 and 1938 are not detailed and are not considered to be "as-built" drawings. Notes from previous inspections conducted during the period 1912 to 1967 were obtained from the Essex County Engineering Department (see pages B-5 through B-10). No other plans, specifications, or computations are available from the Owner, County, or State agencies relative to the design, construction, or repair of the reservoir or embankment.

We acknowledge the assistance and cooperation of personnel from the Essex County Engineering Department, Mr. Samos Nicolosi of the City of Lawrence Engineering Department, personnel at the Lawrence water treatment plant, and Mr. Norm Basavus, caretaker at the reservoir.

- 2.2 Construction Records. The only construction records available are the drawings referred to in Section 2.1, some of which are included in Appendix B. There are no as-built drawings for the embankment or appurtenant structures.
- 2.3 Operating Records. Records of the reservoir level and pumping operations are kept by personnel at the treatment plant.

LAWRENCE RESERVOIR

## 2.4 Evaluation

- a. Availability. There are no as-built drawings or construction records available for the reservoir and embankment.
- b. Adequacy. The lack of hydraulic and structural computations and detailed construction records did not allow for a definitive review. Therefore, the evaluation of the adequacy of the reservoir is based on review of available drawings, visual inspection, past performance history, and engineering judgment.
- c. Validity. Comparison of the available drawings with the field survey conducted during the Phase I inspection indicates that the available information is generally valid. However, it was found that the elevation of the crest of the embankment is about 3 feet higher relative to the rim of the inflow conduit than that shown on a drawing dated 1935 supplied by the Lawrence Water Department. This appears to be a result of a raising of the rim of the inflow conduit rather than a change in embankment height. The embankment since was never raised, according to the Lawrence Water Department.

The elevation of the bottom of the reservoir was determined by subtracting the depth of water at the maximum operating pool (27.5 feet) from the elevation of the top of the stone lining (El 208.4). This results in the bottom of the reservoir at about El 181, as compared with El 177 shown on the 1935 drawing. The inverts of the outflow conduits were determined using this elevation for the bottom of the reservoir.

LAWRENCE RESERVOIR

SECTION 3  
VISUAL INSPECTION

3.1 Findings

- a. General. The Phase I Inspection of Lawrence Reservoir was conducted on April 12, 1979. A copy of the periodic inspection checklist is included in Appendix A. Previous inspections of the reservoir were conducted by the Essex County Engineering Department during the period 1912 to 1967 (see pages B-5 through B-10). The only deficiency noted in the past was seepage into the access tunnel to the gate chamber. This condition was reported in 1926, 1931, 1943, and 1945.
- b. Dam (reservoir and embankment). Lawrence Reservoir consists of a 1870-foot long, earth embankment surrounding most of a 410-foot by 700-foot stone-lined reservoir. The embankment has a maximum height of 29 feet. There is an earthfill dike separating the reservoir into a north and a south basin. There is also a gate house where outflow conduits carry water out of the reservoir and into water supply lines.

The reservoir and embankment are generally in good condition. There was no seepage observed on the outside slopes or at the toe of the embankment. The crest of the embankment is fairly level and straight. There is minor longitudinal cracking of the asphalt pavement on the crest. Also, the iron fence on the inside edge of the crest is tilted toward the reservoir in places. The stone blocks lining the inside of the reservoir are in good condition where visible above the water line. The upper portion of the inside slopes are covered with grass and show no signs of sloughing or erosion. The outside slopes are well-graded and covered with grass. Erosion due to pedestrians and/or recreational use was observed in places on the outside slopes of the the reservoir, especially at the northeast corner of the

LAWRENCE RESERVOIR

reservoir (see photograph No. 6, page C-3). About 10 trees are growing on the outside slopes on the south and west sides of the reservoir.

- c. Appurtenant Structures. The gate house for the reservoir is constructed of brick with a stone masonry foundation. The structure is in good condition. Inside the building, there are three threaded gate stems with hand wheels to operate sluice gates for the screen chamber. The stems are bent, making the gates difficult to operate.

Below the ground surface on the south side of the gate house, there is a chamber which contains three gate valves for the two 30-inch outflow conduits and for the 16-inch drain line from the south basin of the reservoir. The chamber is constructed of brick masonry. There is severe efflorescence on the walls of the chamber, and seepage is also occurring on the north wall. The 30-inch outflow conduits are severely corroded. The gate valves are also severely corroded but are reported to be operable. The 16-inch drain line for the south basin of the reservoir is located in a pit in the floor of the chamber. The pipe and gate valve are corroded, but are reportedly checked periodically. Access to the chamber is from two manholes overhead or from a tunnel which begins at the toe of the embankment. The tunnel is constructed with a brick-lined roof and cut stone walls. There is efflorescence on the walls and roof. Cracking was also observed in the walls and roof at the south end of the tunnel. There are two locked wooden doors at the entrance to the tunnel. Wing walls on each side of the entrance are made of mortared granite blocks. Most of the mortar is missing, and some capstones have shifted.

The 16-inch drain line and gate valve for the north basin of the reservoir are located in a manhole at the toe of the north embankment. There was 1 foot of water in the manhole at the time of the inspection. The drain line is heavily corroded.

#### LAWRENCE RESERVOIR

- d. Reservoir Area. The area immediately around the reservoir is a public park, and there are tennis courts at the toe of the south embankment. Beyond the park on the west, south, and southeast sides of the reservoir, there is dense residential development. A cemetery is located adjacent to the northeast and north sides of the reservoir. It is unlikely that future development would occur. About half the land is covered with grass and about half is covered with houses and roads.
  - e. Downstream Channel. Water flowing out of the reservoir is carried underground in conduits. There is no discharge channel or stream at this site.
- 3.2 Evaluation. The above findings indicate that the reservoir and embankment are in good condition. The facility is generally well maintained, however, there are some deficiencies which require attention. Recommended measures to improve these conditions are stated in Section 7.3.

## SECTION 4

### OPERATING PROCEDURES

- 4.1 Procedures. Water is pumped into the reservoir from a treatment plant located next to the Merrimack River. The reservoir level which is monitored at the treatment plant is also read three times a day at the gate house. There is a caretaker at the reservoir during the day and personnel at the treatment plant continuously.

There are five gate valves which control flow out of the reservoir. Two valves are located on the outflow conduits in an underground chamber at the gate house. These gates are normally kept open. Two emergency shut-off valves are located downstream, one on the supply line for Lawrence and one on the bypass line to Methuen. These are also normally kept open. The fifth gate valve is on a 20-inch line which connects the supply line for Lawrence to the main beneath Ames Street. This valve is normally kept closed. All gate valves are reportedly checked periodically. There are also three sluice gates in the gate house which control flow into the screen chamber. These are normally kept open.

There are two low-level drain lines, one for each basin of the reservoir. The drain valve for the south basin is located in the gate house while the drain valve for the north basin is located in a manhole north of the reservoir. The last time the reservoir was drained was in 1962.

- 4.2 Maintenance of Reservoir and Embankment. The embankment and reservoir are generally well maintained. However, there is local erosion on the outside slopes of the embankment. Also, some trees are growing on the embankment on the south and west sides of the reservoir.
- 4.3 Maintenance of Operating Facilities. Although the valves in the gallery of the gate house are checked periodically, they are severely corroded. The sluice gates are difficult to operate. Emergency shut-off valves on the water supply pipeline and bypass pipeline are located in access wells at the south boundary of the property. These were installed in 1976.

LAWRENCE RESERVOIR

There is seepage and severe efflorescence in the walls of the gate chamber. Cracking and efflorescence was also observed in the roof and walls of the access tunnel to the gate chamber.

- 4.4 Description of Any Warning System in Effect. The water level in the reservoir is monitored continuously by personnel at the treatment plant. If the reservoir rises above the maximum operating level, the pumps can be shut down and the water lowered by demand into the distribution system. However, there is no plan for surveillance of the embankment during and after periods of heavy rainfall or for warning local residents in case of emergency.
- 4.5 Evaluation. There is a program of maintaining the embankment and monitoring the water level at Lawrence Reservoir. However, there is no program of regular technical inspections, a plan for surveillance of the embankment during and after periods of heavy rainfall, or a warning system in effect. This is extremely undesirable considering that the reservoir and embankment are in the "high" hazard category. These programs should be implemented, as recommended in Section 7.3.

#### LAWRENCE RESERVOIR

## SECTION 5

### HYDRAULIC/HYDROLOGIC

#### 5.1 Evaluation of Features

- a. General. Lawrence Reservoir is located on top of a hill and provides equalizing pressure and storage for a water supply. The drainage area consists only of its surface area (6.34 acres). The reservoir level is controlled by pumping from the treatment plant and by the demand of downstream water use. Two 30-inch conduits carry water out of the reservoir and merge to form a 30-inch water supply line for Lawrence. An open 30-inch bypass line from the water supply line directs water to Methuen.

The reservoir is a 410-foot by 700-foot stone-lined structure with an earthfill dike across the middle to form north and south basins. The surrounding embankment is 1,870 feet long and has a maximum height of 29 feet. The maximum operating level is at El 208.4. The maximum storage capacity at this elevation is 44 million gallons (146 acre-feet).

Two 16-inch, low-level drain lines could be used to lower the reservoir in an emergency. Each line services one basin of the reservoir and connects downstream into smaller storm sewers. The drain lines can lower the reservoir by 1 foot in about 3 hours when the water level is at El 208.4. If the drain lines were fully opened, this would result in manholes overflowing downstream, as has been reported in the past. The drain lines should be opened only partially to avoid detrimental effects downstream.

- b. Design Data. There are no hydraulic or hydrologic computations available for the design of the reservoir.

LAWRENCE RESERVOIR

c. Experience Data. The water level is continuously recorded on a chart at the treatment plant and read three times a day at the reservoir. The maximum recorded water level is at El 208.4 which is the maximum operating pool. Personnel from the Lawrence Water Department report that the embankment has never been overtopped.

d. Visual Observations. A gate house is located on the crest of the embankment on the south side of the reservoir. The gate house contains three sluice gates to control flow into a screen chamber. Two 30-inch outflow conduits carry water out of the screen chamber and then merge downstream to form a 30-inch water supply line. The supply line has an open 30-inch bypass line which carries water to Methuen.

Gate valves for the two outflow conduits are located in an underground chamber on the south side of the gate house. The invert of the conduits is at about El 183. There is no high-level overflow pipe for the reservoir.

Sluice gates and gate valves are normally kept open and not used. The sluice gates are difficult to operate. The outflow conduits and gate valves were inspected in the underground gate chamber. The valves, conduits, and flanges are severely corroded. Also, seepage is occurring on the north wall of the chamber. Severe efflorescence was observed on the walls of the gate chamber and on the roof and walls of the access tunnel.

A more detailed discussion of the condition of the reservoir and embankment is given in Section 3, Visual Inspection.

e. Test Flood Analysis. Lawrence Reservoir has been placed in the "small" size category and in the "high" hazard category. In accordance with the Corps of Engineer's guidelines, the full PMF (probable maximum flood) was used to evaluate the capacity of the reservoir.

#### LAWRENCE RESERVOIR

The Test Flood (full PMF) inflow to 6.34 acres of reservoir consists of direct precipitation of 18.16 inches in 6 hours. It was assumed that the inflow due to pumping was equal to the outflow due to water consumption. Normally, when the reservoir level rises to El 208.4, pumping is stopped and outflow continues. With the reservoir level at El 208.4 at the start of the storm, the resulting test flood level is at El 209.9. This elevation is 0.3 foot below the lowest point on the crest of the embankment. Therefore, the reservoir can contain 100 percent of the test flood without overtopping the embankment.

- f. Dam Failure Analysis. The peak discharge rate due to failure of the embankment was calculated to be 14,600 cfs (cubic feet per second). This rate is based on 140 feet of embankment subject to breaching. This would be a section of the south embankment from the gatehouse to the corner of the reservoir, where the downstream hazard is greatest. It is assumed that only one basin of the reservoir would be emptied. Half of the reservoir has been emptied in the past for repairs, and the dike was capable of containing water in the other basin. It would take about 9 minutes for the basin of the reservoir to drain.

Failure of the embankment would produce a flood wave with an initial height of about 7 feet and with a velocity of about 34 feet per second. Alternative areas that would be impacted by a failure of the embankment are shown on the Location Map. If the failure occurs along the south or southeast sides of the reservoir, the flood wave would flow into areas of dense residential development beginning about 100 feet downstream. It is likely that this would cause the loss of more than a few lives and excessive damage to property. If the failure occurs on the north or northeast sides of the reservoir, the flood wave would flow through a cemetery and then into residential areas and factories located 1200 to 2000 feet downstream. It is likely that this could cause the loss of a few lives and appreciable damage to property.

#### LAWRENCE RESERVOIR

For these reasons, the reservoir and embankment have been placed in the "high" hazard category.

LAWRENCE RESERVOIR

## SECTION 6

### STRUCTURAL STABILITY

#### 6.1 Evaluation of Structural Stability

- a. Visual Observations. The evaluation of the structural stability of the embankment surrounding most of Lawrence Reservoir is based upon the review of available drawings, a review of previous inspection reports, and visual observations conducted on April 12, 1979.

As discussed in Section 3, Visual Inspection, the reservoir and embankment are in good condition. No seepage through the embankment was observed at the site. There is local erosion of the outside slopes of the embankment due to pedestrians and/or recreational activities. Also, there are some trees growing on the outside slopes of the south and west sides of the reservoir.

- b. Design and Construction Data. The construction of Lawrence Reservoir was completed in 1875. The contractors were John B. Dacey Co. and Patrick Kevuew. The only data available on the design and materials of the embankment are a drawing dated January 1874 (Figure B-3) and notes given in an early inspection report (pages B-5 and B-6). The data indicate that there is an impervious core of puddled clay 40 feet high which extends from 2 feet below the crest of the embankment to 12 feet below the bottom of the reservoir. The core is 4 feet thick at the top and 12 feet thick at the bottom. The drawing also shows a 2-foot thick blanket of puddled clay extending horizontally from the core to the bottom of the reservoir. The inspection report also mentions that the outflow conduits were "laid in puddle with brick cut-off walls". There is no indication of the zoning or composition of the remaining embankment fill.

The lining of the inside slopes of the reservoir is shown to be 16-inch thick, cut stone blocks laid on top of about 8 inches of gravel.

LAWRENCE RESERVOIR

The lining of the bottom of the reservoir is shown to be a layer of 6-inch cobbles laid on top of about 1 foot of gravel.

- c. Operating Records. There is no instrumentation of any type in the embankment of Lawrence Reservoir, and no instrumentation was ever installed at this site. The performance of the embankment under prior loading can only be inferred by physical evidence at the site.
- d. Post-Construction Changes. Notes from previous inspections (see pages B-8) indicate that post-construction repairs were made at the reservoir in 1935 and 1939. In 1935, the outside slopes on the north and east sides of the reservoir were stripped, reloamed, and reseeded. In 1939, the lining of the inside slopes of the reservoir was grouted "to stop any seepage and make it easier to keep the reservoir clean".
- e. Seismic Stability. Lawrence Reservoir is located in Seismic Zone No. 3, indicating that there is a potential for major damage due to earthquakes in this area. This classification is based on the intensity of past earthquakes and does not indicate the probability of such events in the future. The highest intensity earthquakes for this area were VII and VIII on the Modified Mercalli Scale, and occurred in 1727 and 1755, respectively. There is no record of any major seismic events since 1875 when the reservoir was completed.

There is insufficient data available at this time to evaluate the seismic stability of the embankment. Information is required on the in situ properties of the embankment material, impervious core, and the foundation material. Considering that the reservoir and embankment are in the "high" hazard category, a static and seismic evaluation of the embankment should be conducted as recommended in Section 7.2.

#### LAWRENCE RESERVOIR

## SECTION 7

### ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

#### 7.1 Dam Assessment

- a. Condition. Based upon a review of the available data, the visual inspection of the site, and limited operating information, there are deficiencies which must be corrected to assure the continued performance of Lawrence Reservoir. The reservoir and embankment are generally in good condition. The following deficiencies were observed at the site: seepage and severe efflorescence on the walls of the gate chamber, efflorescence and local cracking in the access tunnel to the gate chamber, severe corrosion on the outflow conduits and gate valves, difficulty operating the sluice gates, local erosion on the outside slopes of the embankment and trees growing on the embankment slopes on the south and west sides of the reservoir.

A test flood inflow (full PMF) of 18.16 inches of rain during a 6-hour period will result in the reservoir at El 209.9. This is based on the assumption that the rate of inflow due to pumping is equal to the rate of outflow due to consumption. The test flood pool is 0.3 foot below the lowest elevation on the crest of the embankment. Therefore, the reservoir can contain 100 percent of the test flood without overtopping the embankment.

- b. Adequacy. The lack of detailed design and construction data did not allow for a definitive review. Therefore, the evaluation of the adequacy of the reservoir and embankment is based primarily on review of available data, visual inspection, past performance and engineering judgment.
- c. Urgency. The remedial measures outlined below should be implemented by the Owner within 2 years after receipt of this Phase I Inspection Report.

LAWRENCE RESERVOIR

d. Need for Additional Investigation. Additional investigations to assess the static and seismic stability of the embankment are needed, as discussed below in Section 7.2.

7.2 Recommendations. Due to lack of data concerning the embankment and foundation of Lawrence Reservoir, it is recommended that the Owner employ a qualified engineering consultant to conduct a geotechnical investigation to determine the seismic and static stability of the embankment. The Owner should implement the recommendations of the consultant.

### 7.3 Remedial Measures

a. Operating and Maintenance Procedures. It is recommended that the Owner accomplish the following:

- (1) monitor seepage and efflorescence in the gate chamber and access tunnel; any signs of increased flow and/or signs of loss of fines should be immediately investigated by a qualified engineering consultant;
- (2) repair sluice gates and corrosion on the outflow conduits and gate valves to insure that they remain operable and to repair any leaks which might occur; the valves and gates should be exercised regularly;
- (3) repair areas of erosion on the slopes of the embankment, especially at the north-east corner of the reservoir;
- (4) selectively clear trees and roots from the slopes of the embankment; all excavating for stumps and roots should be backfilled with selected materials;
- (5) conduct technical inspections of the reservoir and embankment on a biennial basis;

## LAWRENCE RESERVOIR

- (6) institute a plan for surveillance of the embankment during and after periods of unusually heavy rainfall and establish a plan to notify nearby residents in case of an emergency at the project.

7.4 Alternatives. There is no practical alternative to implementing the recommendations and remedial measures listed above.

LAWRENCE RESERVOIR

**APPENDIX A**  
**PERIODIC INSPECTION CHECKLIST**

**LAWRENCE RESERVOIR**

## PERIODIC INSPECTION

## PARTY ORGANIZATION

PROJECT LAWRENCE RESERVOIRDATE April 12, 1979TIME 9 A.M.WEATHER ClearPARTY:

- |                         |                         |
|-------------------------|-------------------------|
| 1. <u>Mike Larson</u>   | 6. <u>Carol Sweet</u>   |
| 2. <u>Bob Gough</u>     | 7. <u>Ed Greco</u>      |
| 3. <u>Scott Nagel</u>   | 8. <u>Lyle Branagan</u> |
| 4. <u>Frank Sviokla</u> | 9. _____                |
| 5. <u>Bill Cheechi</u>  | 10. _____               |

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	<u>Embankment</u>	<u>Larson/Greco/Nagel</u>	
2.	<u>Gate House</u>	<u>Larson/Nagel</u>	
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

**PERIODIC INSPECTION CHECK LIST**

PROJECT LAWRENCE RESERVOIR DATE April 12, 1979  
 PROJECT FEATURE Embankment NAME M. Larson  
 DISCIPLINE Geotechnical NAME S. Nagel/E. Greco

AREA EVALUATED	CONDITIONS	
DAM EMBANKMENT	NORTH SIDE	EAST SIDE
Crest Elevation	210.2 to 210.4	210.3
Current Pool Elevation	205.4	205.4
Maximum Impoundment to Date	208.4	208.4
Surface Cracks	None	None
Pavement Condition	Longitudinal cracks in walkway	same as north side
Movement or Settlement of Crest	None visible some undulations near toe of upper slope	None visible
Lateral Movement	None visible	None visible
Vertical Alignment	Flat	Flat
Horizontal Alignment	Good	Good
Condition at Abutment and at Concrete Structures	N/A (not applicable)	N/A (not applicable)
Indications of Movement of Structural Items on Slopes	Railing leans into reservoir, some posts jacked upward	same as north side
Trespassing on Slopes	Bald spots, divits, rutting	Bald spots, divits
Sloughing or Erosion of Slopes or Abutments	Some erosion, spotty, grass missing	Severe erosion at NE corner, spotty elsewhere
Rock Slope Protection - Riprap Failures	Stone lining in good condition	same as north side
Unusual Movement or Cracking at or near Toes	None visible-some undulations at toe of upper slope	None visible
Unusual Embankment or Downstream Seepage	Wet spot beyond toe	None visible
Piping or Boils	None	None
Foundation Drainage Features	None	None
Toe Drains	None	None
Instrumentation System	None	None

## PERIODIC INSPECTION CHECK LIST

PROJECT LAWRENCE RESERVOIR DATE April 12, 1979PROJECT FEATURE Embankment NAME M. LarsonDISCIPLINE Geotechnical NAME S. Nagel/E. Greco

AREA EVALUATED	CONDITIONS	
DAM EMBANKMENT	SOUTH SIDE	WEST SIDE
Crest Elevation	210.2 to 210.3	210.3 to 210.6
Current Pool Elevation	205.4	205.4
Maximum Impoundment to Date	208.4	208.4
Surface Cracks	None	None
Pavement Condition	Cracks in walkway	same as south side
Movement or Settlement of Crest	None visible	None visible
Lateral Movement	None visible	None visible
Vertical Alignment	Flat	Flat
Horizontal Alignment	Good	Good
Condition at Abutment and at Concrete Structures	N/A	N/A
Indications of Movement of Structural Items on Slopes	Railing tilted into reservoir	same as south side
Trespassing on Slopes	Sidewalks and recreational use	same as south side
Sloughing or Erosion of Slopes or Abutments	Some divits	Some divits
Rock Slope Protection - Riprap Failures	Stone lining good condition	same as south side
Unusual Movement or Cracking at or near Toes	None	None
Unusual Embankment or Downstream Seepage	None	None
Piping or Boils	None	None
Foundation Drainage Features	None	None
Toe Drains	None	None
Instrumentation System	None	None

PERIODIC INSPECTION CHECK LIST

LAWRENCE RESERVOIR

Additional Notes on Embankment

South Side: One tree at each bench and three trees at or near toe of slope; considerable spalling of steps, some near the bottom have shifted.

West Side: Bushes and small trees landscape top and bottom of slope.

## PERIODIC INSPECTION CHECK LIST

PROJECT LAWRENCE RESERVOIRDATE April 12, 1979PROJECT FEATURE Gate HouseNAME M. LarsonDISCIPLINE GeotechnicalNAME S. Nagel

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE</u>	
a. Approach Channel	Submerged-not visible
Slope Conditions	N/A
Bottom Conditions	Not visible
Rock Slides or Falls	N/A
Log Boom	N/A
Debris	None visible
Condition of Concrete Lining	N/A
Drains or Weep Holes	None visible
b. Intake Structure	Foundation of Gate House
Condition of Concrete	Good condition-mortared granite blocks
Stop Logs and Slots	None-screens only

**PERIODIC INSPECTION CHECK LIST**

**PROJECT** LAWRENCE RESERVOIR

**DATE** April 12, 1979

**PROJECT FEATURE** Gate House

**NAME** M. Larson

**DISCIPLINE** Geotechnical

**NAME** S. Nagel

AREA EVALUATED	CONDITION
<b>OUTLET WORKS - CONTROL TOWER</b>	
a. Concrete and Structural	Granite block foundation and brick masonry superstructure
General Condition	Good
Condition of Joints	Tight-good
Spalling	None
Visible Reinforcing	None
Rusting or Staining of Concrete	None-some staining above water line
Any Seepage or Efflorescence	None
Joint Alignment	N/A
Unusual Seepage or Leaks in Gate	None visible - submerged
Cracks	None visible
Rusting or Corrosion of Steel	None
b. Mechanical and Electrical	
Air Vents	N/A
Float Wells	N/A
Crane Hoist	None
Elevator	N/A
Hydraulic System	N/A
Service Gates	3 sluice gates, difficult to operate, normally kept open
Emergency Gates	N/A
Lightning Protection System	N/A
Emergency Power System	N/A
Wiring and Lighting System in Gate Chamber	N/A

**PERIODIC INSPECTION CHECK LIST**

**PROJECT** LAWRENCE RESERVOIR  
**PROJECT FEATURE** Gate Chamber and Access Tunnel  
**DISCIPLINE** Geotechnical

**DATE** April 12, 1979  
**NAME** M. Larson  
**NAME** S. Nagel

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - TRANSITION AND CONDUIT</u>	
General Condition of Concrete	see notes below
Rust or Staining on Concrete	
Spalling	
Erosion or Cavitation	
Cracking	
Alignment of Monoliths	
Alignment of Joints	
Numbering of Monoliths	

Tunnel Gallery- Arched roof of brick masonry, walls of mortared granite blocks- 4'-9" wide by 8' high-cracking in south end of tunnel roof and walls, efflorescence on roof and walls, no lighting, wooden walkway in fair condition.

Gate Chamber- High arched room of brick masonry, two manholes lead to surface and give access to gate valves. Walls show severe white efflorescence, water seeping from north wall, two 30-inch pipelines and gate valves are severely corroded. Pit in middle of room contains valve for 16-inch drain line, valve operator on wall severely corroded.

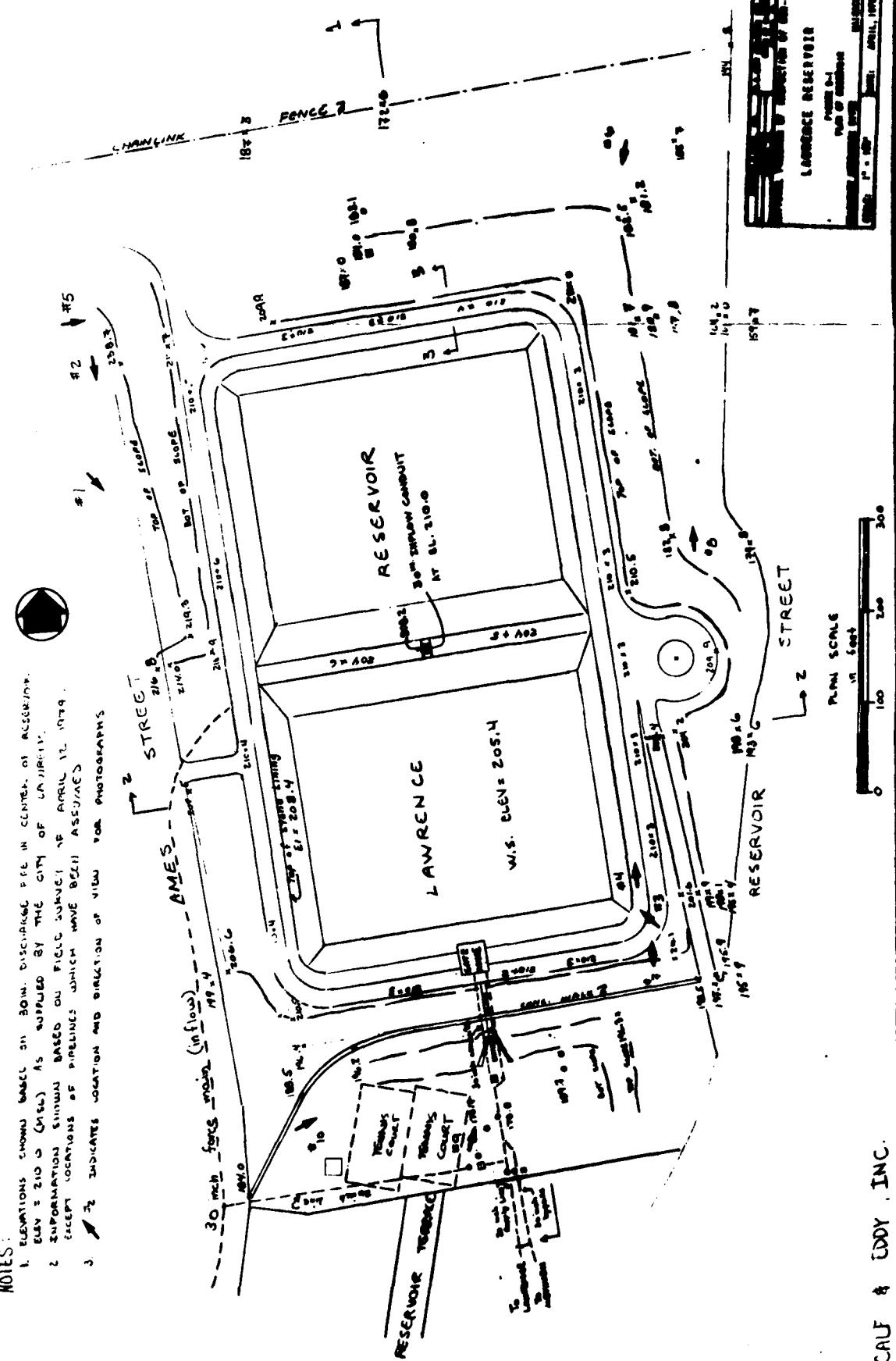
Wing Walls (at entrance to access tunnel)- Mortared granite blocks, most of mortar is missing, capstones have shifted, weeds growing in unmortared joints.

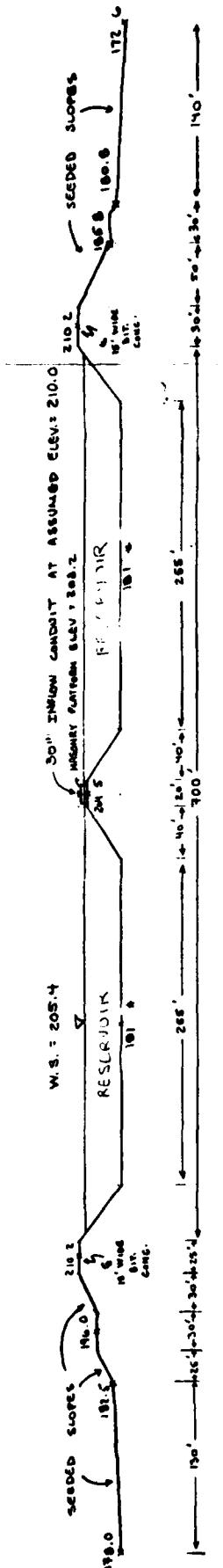
APPENDIX B  
PLANS OF RESERVOIR AND PREVIOUS  
INSPECTION REPORTS

	<u>Page</u>
Figure B-1, Plan of Reservoir from Field Survey, April 12, 1979	B-1
Figure B-2, Sections through Reservoir from Field Survey, April 12, 1979	B-2
Figure B-3, Section through Embankment at Gate House, dated January 1874	B-3
Figure B-4, Plan and Section through Gate House from Drawing Dated January 1874	B-4
Inspection Report by Essex County Engineers, May 1912	B-5
Inspection Notes by Essex County Engineers, 1917 to 1967	B-7

LAWRENCE RESERVOIR

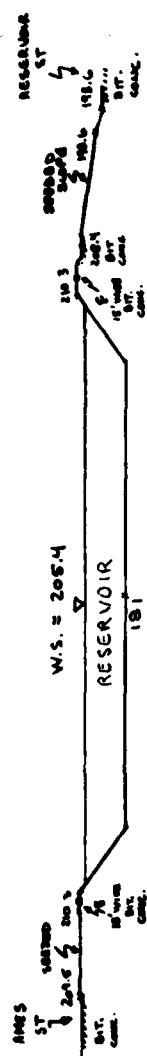
- NOTES:
1. ELEVATIONS SHOWN BASED ON 30IN. DISCHARGE PIT IN CENTER OF ACCORDING.  
ELAV = 210.0 (GSL) AS SUPPLIED BY THE CITY OF LAWRENCE.
  2. INFORMATION SHOWN BASED ON FIELD SURVEY OF APRIL 12, 1979.  
EXCEPT LOCATIONS OF PIPELINES WHICH HAVE BEEN ASSUMED
  3. #2 INDICATES LOCATION AND DIRECTIONS OF VIEWS FOR PHOTOGRAPHS





SECTION I

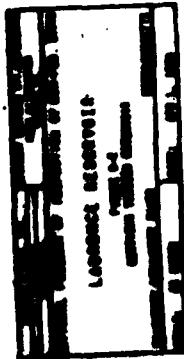
卷之三



SECTION 2-2

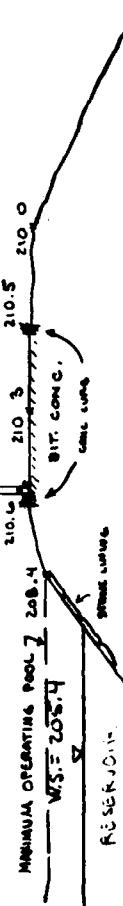


NOTE: SI. NO. 111 CALLED AND BY CORRESPONDING PARAPHRASE  
MANUFACTURED IN CHINA ON DATE (S.I.C.) FEBRUARY  
2000 BY CHINESE COMPANY (S.I.C. 2000)



SECTION 3-3

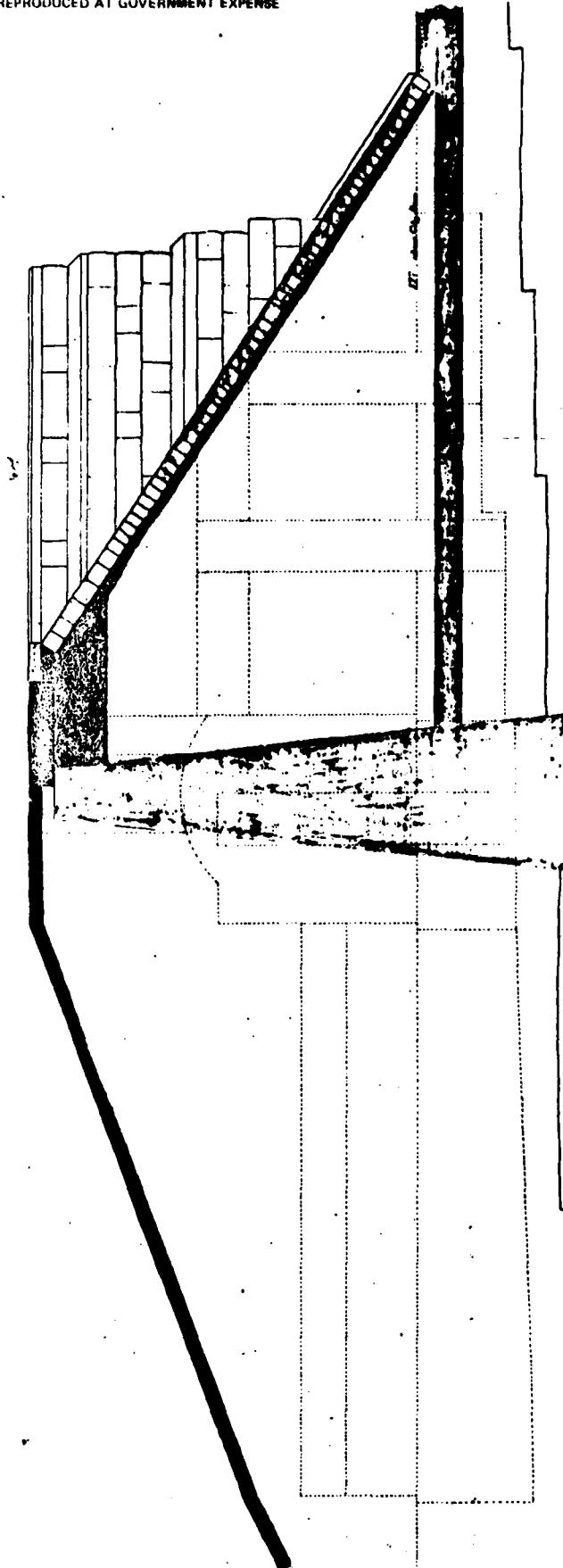
SCALE 1 in = 10 FT



MCALF & EDDY INC.

LAWRENCE WATER WORKS  
EFFLUENT GATE CHAMBERS.  
DISTRIBUTING RESERVOIR.  
June 1910 Elevation.

Scale 1 in = 5 ft.



NOTE: PLAN REDUCED FOR THIS  
REPORT

NOT AS-BUILT DRAWING

FIGURE B-3

LAWRENCE WATER WORKS  
EFFLUENT GATE CHAMBERS  
AT RESERVOIR.  
Schematic

NOTE: NOT AS-BUILT PLAN  
PLAN REDUCED FOR THIS  
REPORT

EFFLUENT GATE CHAMBERS - PLAN.

SECTION THROUGH EAST OPENING  
SHOWING PIPE FROM THE NORTH BASIN.—

FIGURE 1-1

O 1/5-C  
D. R. 3. S.P.

COUNTY OF ESSEX, MASSACHUSETTS  
ENGINEERING DEPARTMENT

Inspection of Dams, Reservoirs, and Stand Pipes

O 1/3-5  
SUB NUMBER  
D. R. 3. S.  
Neg. No. 515

Inspector C. C. Barker Date May 10, 1912 Classification I  
City or Town Lawrence Location Tower Hill (Bodewell's Hill) on  
Omega St.  
Owner Lawrence Water Works Use Water Supply  
Include such details as cores, cut off walls, paving, sodding, class of masonry, kind of cement, (ast. or port.) etc.  
Material and Type Earth embankment with a clay puddle core wall

Elevations in feet: above (+) or below (-) full pond or reservoir level. (Cross out what does not apply.)

For Dam  
 { Bed of stream below ..... Bottom of pond ..... Bottom of spillway ..... Top of dam ..... Top of back boards  
 For Res. or S. P.  
 { Ground surface below ..... Bottom of res. ..... Level of over flow pipe ..... Top of res.  
 For dam .....  
 Length in ft. ..... Top width in ft. ..... Pond area ..... Area of watershed  
 For Res. or S. P. Inside dimensions 700' long by 20' wide 30' dry Capacity 75,000,000 gal. .....  
 Length of overflow or spillway ..... Outlet pipes (size and nature)  
 Stand-pipe; thickness at base ..... diam. at river head ..... Thick <sup>thin</sup>  
 Foundation and details of construction

Constructed by and date 1873-5

Recent repairs and date

Evidence of leakage

Condition Good

S. R. when painted inside

Topography of country below

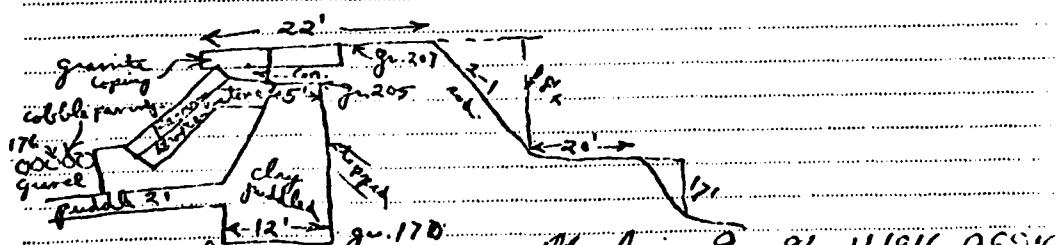
Nature, extent, proximity, etc. of buildings, roads or other property in danger if failure should occur The land on the south & S.W. is thickly settled with houses, cemeteries, Agawam of damage will be done to property & life

Plans and data secured or available

Full agent plans showing all of res. on fill in office of City Eng.

Notes, sketches, sections, etc.

See sheet #2 for abstract of specifications.



\*Severity as to probable damage in case of failure. 3 slight, 2 moderate, 1 serious.

McClaren Fire Nov. 11, 1916 26-14

LAWRENCE RESERVOIR

Fig. #17

Lawrence  
Sheet #2

01/13/50  
Class #3 ..

R 3

Contractor name John B Dacey Co + Patrick Kevaneen  
700 ft. long or 400 ft. wide 30 ft. deep with a division embankment  
22 ft. wide on top slope 2 to 1 granite cap on top inside. Inside 1  
1/2 to 1 inside having a 2 ft. clay puddle wall slope inside per  
with block stone 16" deep small stone between joints. Bottom part  
of gravel on which are stone 18" deep. The granite coping is laid in a bed  
concrete. Hydraulic cut is used. stone masonry in gate chamber  
overfalls wing walls are of cut granite stone or cut face ashlar  
masonry slopes paved with flagging (North River) joints pointed with  
cement. Outlet inlet pipe (30") laid in puddle with brick cut off  
walls.

LAWRENCE RESERVOIR

Lawrence R. 3

Contractor's name, John B. Dacey Co. & Patrick Kewucew, 700 ft. long, 400 ft. wide, 30 ft. deep with a division embankment 22 ft. wide on top slopes 2 to 1, granite cap on top inside. Inside slope 1 1/2 to 1. Inside having a 2 ft. clay puddle wall. Slope inside paved with block stone 16" deep small stones between joints. Bottom paving of gravel on which are stone 18" deep. The granite coping is laid in a bed of concrete. Hydraulic cement is used. Stone masonry in gate chamber, overfalls and wing walls are of cut granite stone or cut face ashler masonry slopes paved with flagging (North River) joints pointed with cement. Outlet and inlet pipes (30") laid in puddle with brick cut off walls.

1917, March 26. Max. Ht. 40. ft. Apparent condition, Good. —

1926, Nov. 4. R. R. Evans, Insp. with Alderman MacNulty. This is a large earth reservoir with a capacity of some 40,000,000 gallons or perhaps a little more, and so far as could be ascertained, is in first class shape. There is no core wall, but a clay puddle which according to the plans is about twelve feet wide on the base. The embankments are well sodded and show no signs either of washing or of seepage from the water in the reservoir. There is no spillway and no tributary drainage area. The structure was built in 1875 and is in a position where failure would be very serious. Access can be had through a tunnel to a well at about the center of the dam where the outlet pipes emerge. A little water is standing on the floor of this tunnel and of the well but this seems to be a general seepage and not confined to any one locality. There is nothing whatever to indicate that any part of the work is not in good shape.

1926 Report to Co. Comm. This is a large earth reservoir with a capacity of more than 40,000,000 gallons, said to be divided into two compartments. There is no core wall, but a clay puddle core which according to the plans is about twelve feet wide on the base. There is no spillway and there is no tributary drainage area. The structure was built in 1875 and is in a location where complete failure might be a very serious matter. A careful examination of the embankments which are well sodded and kept in good condition reveals no evidence either of washing or of seepage through the banks. Access can be had through a tunnel to a well at about the center of the dam where the outlet pipes emerge. The floor at this point is wet with pools of water standing in places, but there is no indication that this comes from any one point and it is apparently a general seepage not due to any well defined leak. Inspection seems to indicate that the entire structure is in good shape.

1929, Nov. 25. C. C. Barker, Insp. There are a great many houses and a cemetery in the vicinity of this reservoir, and there would be a great deal of damage in case of failure, and it is very likely there would be loss of life. The reservoir is in very good condition and well kept, and I saw no evidence of leakage. The conditions are the same and there have been no changes since the last inspection.

1929 Report to Co. Comm. The reservoir on Tower Hill at Ames Street, belonging to the Lawrence Water Works, is apparently in excellent condition and shows no signs of leakage.

Lawrence R. 3

1931, Oct. 15, C. C. Barker, Insp. I saw Mr. Callahan, Foreman, L. W. W., who had one of the men show me the tunnel at the end of the reservoir near the gate house. It is somewhat damp in the tunnel and probably there is a very slight seepage, but nothing of any consequence. The reservoir and slopes are kept in good condition. There have been no changes since the last inspection and conditions are the same.

1931 Report to Co. Comm. It is a large and important reservoir, apparently in good condition. The slope and the grounds around it are well kept up and conditions are the same as at the last inspection.

1933, Sept. 12. C. C. Barker, Insp. I left a copy of the notice at the work shop on Oak Street for Mr. Callahan, Foreman. Mr. Murphy went to the reservoir with me and through the tunnel at the end of the reservoir near the gate house. The reservoir is in good condition. There have been no changes since the last inspection, and conditions are the same, except that a new pump has been installed in a new building below the reservoir. This pump has been installed to pump into the standpipe.

1933 Report to County Commissioners. Safe and in reasonable good condition.

1935 Sept. 27, C.C. Barker Insp. I left a copy of the notice at work shop on Oak Street for Mr. Mahoney. The water level was about from the top today. The inside paving is in good shape. The north and east slopes have been stripped and some new loam put on for new seeding. The work is not completed. There are no signs of leakage. Today the walls at the head of the tunnel are dry and there is no seep. On the west outlet pipe at the south joint of the valve there is moist around the calking, it looks as if there might be a slight leak. The reservoir is in good condition.

1935 Report to Co. Comm. Safe and in reasonably good condition.

1937 July 20, C.C.Barker, Insp. I left a copy of the notice at the work shop on Oak Street for Mr. Mahoney. The reservoir is full and is in good condition. There are no signs of leakage.

1937 Report to Co. Comm. Safe and in reasonably good condition.

1939 August 29, C.C.Barker, Insp. I gave a copy of the notice to Patrick S. Nugent, Supt., who was at the reservoir. Joseph Scully is foreman at the reservoir. Apparently the reservoir is in good condition and there are no signs of leakage. The reservoir is only partly full as men are working on the inner slopes. They are growing and plastering with cement the inner slope paving to stop any seepage and make it easier to keep the reservoir clean. The north basin has been partly done, but cannot be completed until they can drain this portion of the reservoir. This cannot be done until a leak in the pipe that runs through the south basin is repaired. North of reservoir they are laying a 12" pipe to connect with a storm sewer. This will drain the chamber into which empties the 16" chain pipe that passes through the north embankment of the reservoir. This 16" pipe

Lawrence R. 3

drains the north basin of the reservoir and was laid when the reservoir was constructed. This work will not affect the stability of the reservoir.

1939 Report to Co. Comm. Safe and in reasonably good condition.

1941 Sept. 26, C.C.Barker, Insp. I gave a copy of the notice to Joseph Scully for Mr. Nugent, Supt. All repairs have been completed since the last inspection and the reservoir is in good condition. The walls at the head of the tunnel are dry and there is no seepage.

1941 Report to Co. Comm. Safe and in reasonably good condition.

1943 Aug. 17, S.W.Woodbury, Insp. I gave a copy of the notice to Mr. Scully, who inspected the reservoir with me. John W. McCarthy, Jr. is now Supt. of the L. W. W. There is some seepage through the tunnel walls. A small pump in the building southwest of the reservoir is being used for the first time today to pump water to the tower. This pump not used during the last three years. Previously the pumps at Water Street had been used for this purpose. There is some water on the floor of the tunnel.

1943 Report to Co. Comm. Safe and in reasonably good condition.

1945 Aug. 23, S.W.Woodbury, Insp. Gave a copy of the notice to Mr. Scully for Mr. McCarthy. Water level today: 22.5. There is still water on the tunnel floor. Condition of the dam is the same.

1945 Report to Co. Comm. Safe and in reasonably good condition.

1947 Oct. 3, S.W.Woodbury, Insp. Gave a copy of the notice to Mr. Cronin for Mr. Scully and went to reservoir alone. Condition is the same.

1947 Report to Co. Comm. Safe and in reasonably good condition.

1949 Sept. 26, S.W.Woodbury, Insp. Gave a copy of the notice to Mr. Scully for Mr. Callahan, Water Commissioner. Mr. Scully went to dam with me. Condition of the dam is the same.

1949 Report to Co. Comm. Safe and in reasonably good condition.

1951 Oct. 15, E.H.Page, Insp. Gave a copy of the notice to Mr. Joe Scully at the gate house at the reservoir, who went to the reservoir with me. Condition of the reservoir is the same.

1951 Report to Co. Comm. Safe and in reasonably good condition.

1953 Sept. 30, E.H.Page, Insp. Gave a copy of the notice to Mr. Joseph Scully at gate house of reservoir, who went to reservoir with me. Condition: same.

1953 Report to Co. Comm. Safe and in reasonably good condition.

1954, May 25, E.H.Page, Insp. No leaks. Good condition of tanks. Condition of dam: Same - good.

1955, Nov. 18. E.H.Page, Insp. Owner's Agent: Mr. Scully. Condition: Same.

Lawrence R. 3

R. 3 Sh. 4

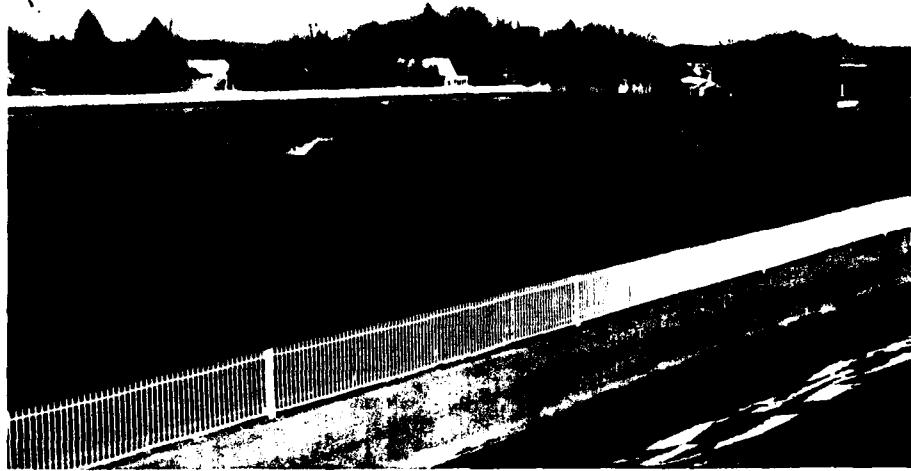
- 1955 Report to Co. Comm. Safe and in reasonably good condition.  
1957, Dec. 5, E.H.Page, Ins. Condition: Same.  
1957 Report to Co. Comm. Safe and in reasonably good condition.  
1959 Sept. 21, E.H.Page, Insp. Condition: Same.  
1959 Report to Co. Comm. Safe and in reasonably good condition.  
1961 Nov. 28, E.H.P. & P.D.K. Insps. Condition: Same.  
1961 Report to Co. Comm. Safe and in reasonably good condition.  
1964, Feb. 12 Condition: Safe.  
1963 Report to Co. Comm. Safe and in reasonably good condition.  
1965 June 14, 1966 P.D.K. Insp. Safe and good condition.  
1965 Report to Co. Comm. Safe and in reasonably good condition.  
1967 Jan. 24, 1968. Safe and good condition.  
1967 Report to Co. Comm. Safe and in reasonably good condition.

LAWRENCE RESERVOIR

APPENDIX C  
PHOTOGRAPHS

(For location and direction of view of photographs, see  
Figure B-1 in Appendix B).

LAWRENCE RESERVOIR



**NO. 1 VIEW OF INFLOW CONDUIT AND DIKE  
SEPARATING NORTH & SOUTH BASINS**

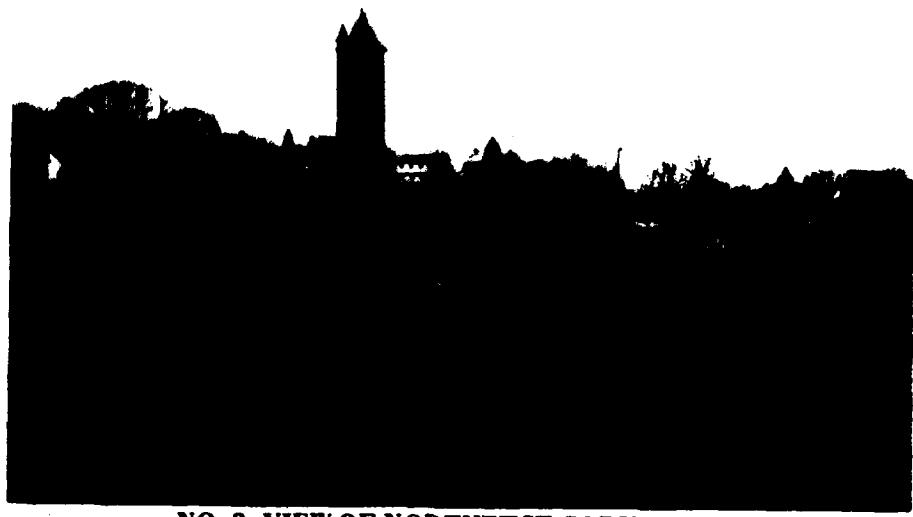


**NO. 2 VIEW OF WEST SIDE OF RESERVOIR AND GATE HOUSE**

LAWRENCE RESERVOIR

C-1

REPRODUCED AT GOVERNMENT EXPENSE



**NO. 3 VIEW OF NORTHWEST CORNER OF  
RESERVOIR AND WATER TOWER**



**NO. 4 LINER ON INSIDE SLOPE OF RESERVOIR**

**LAWRENCE RESERVOIR**

**C-2**

**REPRODUCED AT GOVERNMENT EXPENSE**

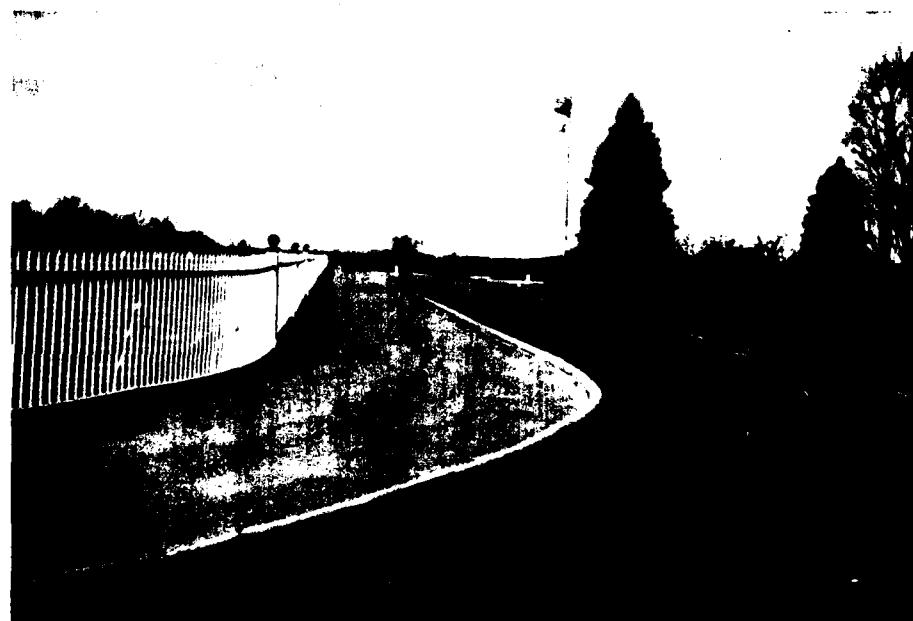


**NO. 5 EMBANKMENT ON NORTH SIDE OF RESERVOIR**



**NO. 6 EROSION OF EMBANKMENT AT  
NORTHEAST CORNER OF RESERVOIR**

LAWRENCE RESERVOIR



**NO. 7 CREST OF EMBANKMENT ON EAST SIDE OF RESERVOIR**

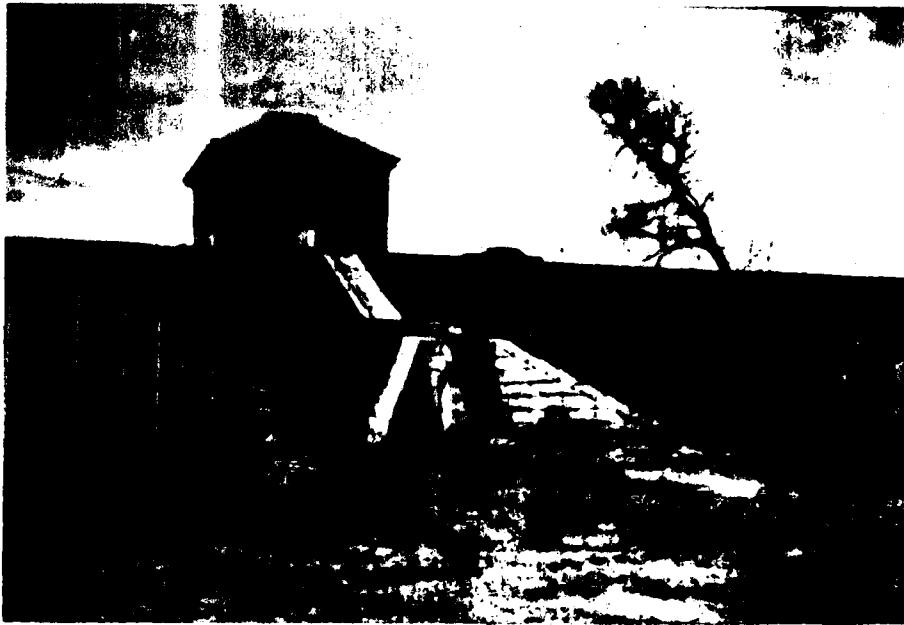


**NO. 8 EMBANKMENT ON EAST SIDE OF RESERVOIR**

LAWRENCE RESERVOIR

C-4

REPRODUCED AT GOVERNMENT EXPENSE



**NO. 9 GATE HOUSE AND TUNNEL ENTRANCE  
ON SOUTH SIDE OF RESERVOIR**



**NO. 10 EMBANKMENT ON SOUTH SIDE OF RESERVOIR**

LAWRENCE RESERVOIR

**APPENDIX D**  
**HYDROLOGIC AND HYDRAULIC**  
**COMPUTATIONS**

**LAWRENCE RESERVOIR**

Project Nat. Review of Non Fed. Dam Acct. No. 5917 Page 1 of 3  
Subject ESSEX County, Mass Comptd. By LEB Date 6/21/79  
Detail LAWRENCE PFERVOIR Ch'd. By C.I. Date 6/21/79

## I) PMP Storm Inflow

A - Rainfall

6 hr rain	:	22.7 in. x 0.8 = 18.16 in.
12 hr	"	18.16 in. x 1.11 = 20.16 in
24 hr	"	" x 1.20 = 21.79 in
48 hr	"	" x 1.27 = 23.06 in.

### B. Tributary Area

Surface drainage from areas outside of the curb at the fence line should be diverted elsewhere. The area within the curb line is:

### C - Rainfall Storage Volume

Reservoir has no spillway or high level waste pipe. The level is controlled by pumping and by water use. For this evaluation, it is assumed that pumped inflow exactly equals water use. Also, it is assumed that the reservoir level is at elevation 208.4 (the top of the reservoir lining) at the start of the storm.

Arc. at elev. 208.4 :

$$\begin{array}{rcl} 688 \times 398 = & 273824 \text{ ft}^2 \\ \underline{\text{less } [(88)^2 - \pi(44)^2]} & \underline{- 1662 \text{ "}} \\ & 272162 \text{ ft}^2 \text{ or } 6.25 \text{ acres} \end{array}$$

$$\text{Storage Vol. for Rarii} = \frac{1}{2}(6.34 + 6.25)(210.6 - 208.4) = 13.85 \text{ ac ft.}$$

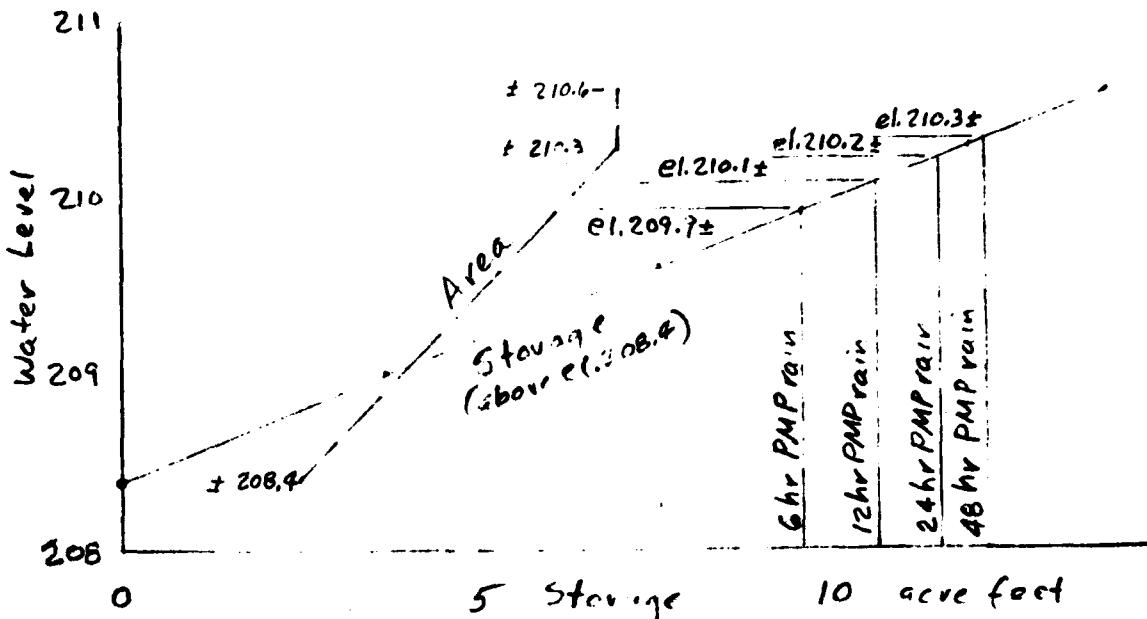
## D - Rain inflow Volume

$$\text{Volume} = (\text{in. of rain}) \left(\frac{1}{2}\right) (\text{trib area})$$

Time Period :	6 hr	12 hr	24 hr	48 hr	
Total Volume	9.59	10.65	11.31	12.18	< 13.05

Project Nat. Review of Non Fed. Dams Acct. No. 5917  
 Subject ESSEX County, Mass. Comptd. By L.E.B Page 2 of 3  
 Detail LAWRENCE RESERVOIR Chkd. By J.H. Date 6/21/79

(II) Maximum Water Level - due to rain only



0                    5 Storage            10 acre feet

Res. Level	Area	Ah	Water level	$\Sigma$ Inc. Vol (from rain)
208.4	6.25	0.6'	209.0	0 ac. ft
209.0	6.28	0.6'	209.6	3.76
209.6	6.31	0.7'	210.3	7.54
210.3	6.34	0.3'	210.6	11.96
				13.86

(III) Reservoir Drainage

$$1-16'' \text{ drain} - \text{assume } 350' \text{ long to M.H. where } H = 170' \text{ is assumed} \\ H = (208.4 - 170) = 38.4' = h_v [1 + 5 + \frac{38.4^2}{170} \cdot (0.02)] = 6.75 \text{ hr}$$

$$\therefore V = 19.1 \text{ fpm}, Q \approx 27 \text{ cfs}$$

$$\text{Time to drain } 1' \text{ at ave. el. 208.4} = \frac{272.167}{27(300)} = 2.8 \text{ hours} \left[ \begin{array}{l} \text{no inflow or outflow} \\ \text{1 ft drain} \end{array} \right]$$

Project Nat. Review of Non Fed. Dams Acct No. 6356  
 Subject ESSEX COUNTY, MASS. Comptd. By L.E.B.  
 Detail LAWRENCE RESERVOIR Chkd. By W.C.

Page 3 of 3  
 Date 5/22/79  
 Date 7/10/79

(IV)

## Failure of Dam

### Peak Failure Flow:

Pond Elevation - 209.9 (6 hr rain)  
 Toe Elevation - 181.0 (ave bot.)

$$Y_0 = 28.9$$

Dam Length Subject to Breaching = 140 ft

$$W_0 = 40\% (140) = 56 \text{ ft}$$

Area of highest downstream hazard is south embankment where gate house would prevent a wider breach.

$$Q_{P_1} = 1.68 W_0 (Y_0)^{1.5} = 1.68 / 56 : (28.9)^{1.5} \cong 14,600 \text{ cfs}$$

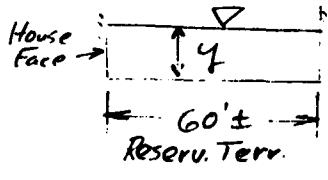
### Storage Volume Released:

$$\text{Storage Above Spillway} \text{ Cen. Wall } 5.9(700+410+685+385)^{\frac{1}{2}} = 34.1 \text{ acft}$$

$$\text{Storage Below Spillway} \text{ " " } 23.5(375+385+250+325)^{\frac{1}{2}} = 55.7 \text{ " "$$

$$S = \text{Total Storage} = (\text{south pool + north pool above cen. wall}) \quad 89.8 \text{ " "$$

### Channel Hydraulics:



$$S = \frac{I_0}{300} = .0333; n = .03, A = 60y, R \approx y$$

$$V = \frac{1.49}{.03} y^{\frac{2}{3}} S^{\frac{1}{2}} = 9.07 y^{\frac{2}{3}}$$

y	A	V	Q
10	600	42	25,300
15	900	55	49,600
13	780	50	39,100
8	480	36	17,400
7	420	33	13,900

Failure above Reservoir Terrace could produce flow about 7 feet deep at  $\pm 34$  fps (theoretical) down that street, probably causing many deaths!

Failure at the northeast corner would pass thru a graveyard which is likely to absorb energy from the failure flow, before it reaches the lower lying factories or residences.

### Time to Drain:

$$\frac{43560}{3600(\frac{1}{2})(14,600)} = 0.15 \text{ Hours, or } 9 \text{ Min.}$$

APPENDIX E  
INFORMATION AS CONTAINED IN THE  
NATIONAL INVENTORY OF DAMS

LAWRENCE RESERVOIR

**END**

**FILMED**

**7-85**

**DTIC**